

TMDLS FOR
CADMIUM, COPPER, AND ZINC
IN THE HASSAYAMPA RIVER
HUC# 15070103-007



Prepared by:
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Water Quality Division
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October 2, 2002

APPROVAL NOTICE

This report, *TMDL's for Cadmium, Copper, and Zinc in the Hassayampa River HUC# 15070103-007*, was submitted for approval to the U.S. EPA, Region 9 (EPA) on October 2, 2002. At the time of submission, changes to Arizona's surface water quality standards had been proposed but not yet approved by the EPA. In anticipation of EPA's approval of the proposed standards, this report included calculations based on both the current and the proposed standards. In the Staff Report Supporting Approval of TMDLs, the following was stated.

The TMDL submittal included two sets of applicable water quality standards for dissolved metals. The numeric standards based on ADEQ 1996 and the "proposed" numeric standards for triennial review by ADEQ in 2002. On October 22, 2002, EPA approved the proposed dissolved metal standards; therefore these TMDLs are hereby approved and to be interpreted via these new numeric standards for dissolved cadmium, copper and lead.

Calculations based on both sets of standards will remain in this report; however, the calculations which state they are, "based on Proposed Standards", are the calculations supporting the approved TMDLs.

EXECUTIVE SUMMARY

The Hassayampa River from its headwaters to its confluence with Blind Indian Creek (HUC# 15070103-007) is listed as “water quality limited” by the State of Arizona according to the provisions of the Clean Water Act Section 303(d). The Arizona Department of Environmental Quality (ADEQ) listed the reach for non-attainment of Aquatic and Wildlife warm water designated use standards for cadmium, copper, and zinc. This document establishes Total Maximum Daily Loads (TMDLs) for these dissolved metals in the surface waters of the Hassayampa River.

To verify and quantify the pollutant loads, the ADEQ TMDL Program conducted a watershed wide sampling effort. The results demarcated a two mile stretch of metals impairment in the upper reaches of the watershed. Several significant sources were identified within this stretch: the Wetlands tailings pile, the Maple Gulch drainage including the McClellan tailings piles, and the Senator Gold Mine adit and tailings pile. Currently, there are no permitted point source discharges in the watershed. Exceedances of applicable standards were not observed downstream of the impaired stretch.

The TMDLs have been calculated based on real loads at low flow and spring runoff critical conditions. Cadmium, copper, and zinc loads were calculated for each of the sources in a spreadsheet containing formulas for natural background and measured loads, the TMDLs, wasteload and load allocations, and the necessary load reductions. An explicit margin of safety (MOS) of 10% was applied to the TMDLs to account for laboratory and analysis error. An additional implicit MOS was incorporated into the modeling using conservative considerations including: use of the more restrictive water quality standards for cadmium and copper based on proposed changes in designated uses predicated on elevation of the affected reach, and calculation of the TMDLs using chronic exposure criteria.

These TMDLs are being developed under a phased approach. This document presents the first phase of an overall effort to bring the surface waters of the Hassayampa River into compliance. This phase was designed to verify the water quality concerns, to identify sources of pollution, to determine the water quality goals in the affected subwatershed, and to recommend actions to reduce pollutant loading. The second phase is intended to collect additional data, to refine loading as necessary, and to expand on the implementation plan.

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1.0 WATERSHED DESCRIPTION

1.1 Overview

The Hassayampa River is located in Yavapai County in central Arizona. It is an 112 mile tributary to the Gila River within the Middle Gila basin. Its headwaters originate in the Bradshaw Ranger District of Prescott National Forest at an elevation of 7,400 feet above mean sea level (ft msl). The river flows northwest approximately eight miles from its headwaters near Mt. Union before assuming a southerly flow direction. At an elevation of 3,350 ft msl, approximately 31 miles downstream from the headwaters, Blind Indian Creek flows into the Hassayampa River. The listed reach HUC#15070103-007 ends at this confluence (Figure 1).

ADEQ intends to segment HUC#15070103-007 at the confluence of Copper Creek. This division at 5,000 ft msl coincides with research by the ADEQ Biocriteria Program indicating that perennial streams above 5,000 ft msl generally have cold water macro-invertebrate communities while those below 5,000 ft msl generally have warm water macro-invertebrate communities (ADEQ, 2002b). The proposed segmenting of the reach at 5,000 ft msl also correlates to transitions in climatology, geology, vegetation, wildlife, and land use within the subwatershed. The following discussions refer to HUC#15070103-007A as the upper or upstream reach and HUC#15070103-007B as the lower or downstream reach.

1.2 Climatology

The amount of precipitation differs significantly between the upper and lower reaches of the Hassayampa River. The upper reach lies at elevations between 5,000 and 8,000 ft msl and receives approximately 20 to 25 inches of precipitation per year, falling as snow in the winter months. The lower portion of the watershed lies between 3,000 and 5,000 ft msl and receives an annual precipitation of 10 to 20 inches, predominantly as rain. Both regions receive precipitation according to a bimodal pattern, with most of the rain occurring from mid-July through mid-September as short-lived intense monsoon thunderstorms, and gentler storms of longer duration occurring during winter months (Sellers, 1974).

Two Flood Control District of Maricopa County (FCDMC) rain gages are located within the watershed. The rain gage at Mt. Union (#5380), near the headwaters of the Hassayampa River, has a period of record from 1982 to present. In the lower

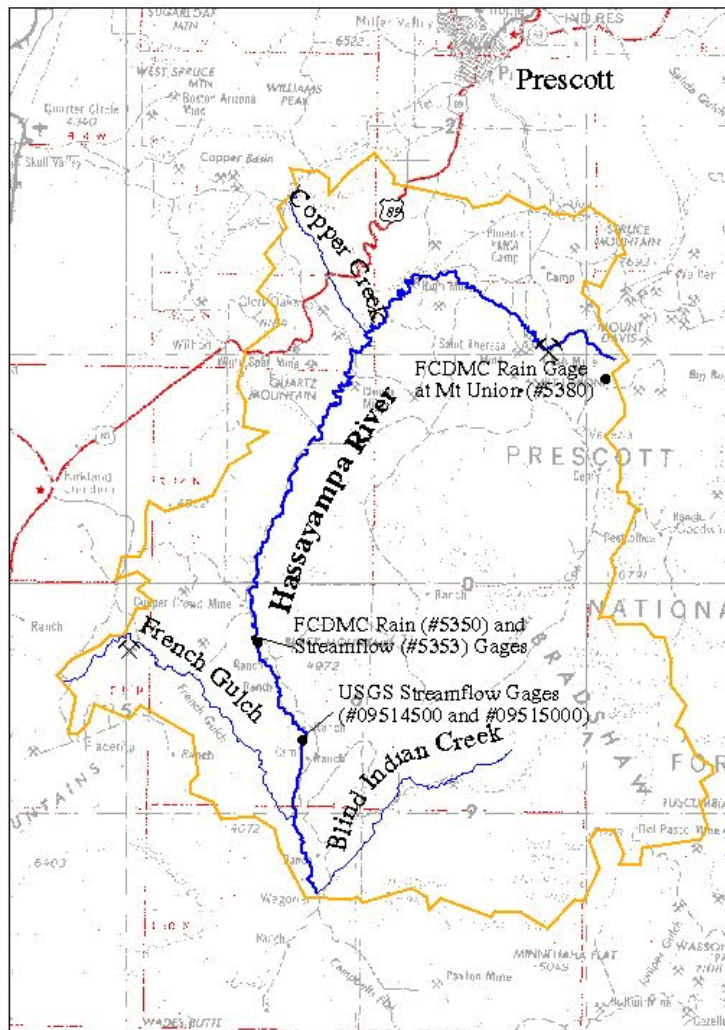


Figure 1.
Hassayampa River
Watershed

HUC: 15070103-007
Basin: Middle Gila
Location: Yavapai County
Watershed Area: 220 square miles
Reach Length: 31 miles
Elevation Range: 3350 - 7400 ft msl

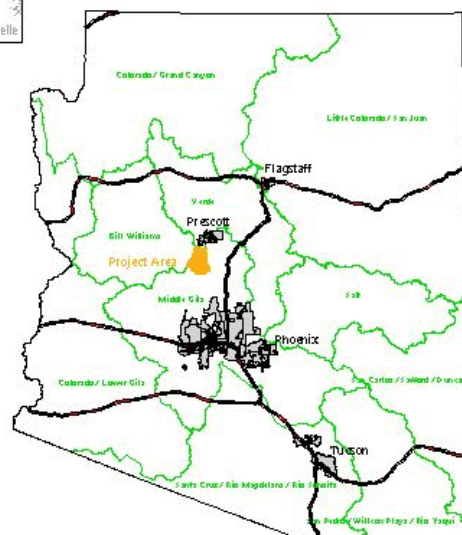


2 0 2 4 6 Miles

Legend:

- Basins
- Hassayampa River Sub-Watershed
- Rivers
- Highways
- Cities

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watershed, the rain gage on Wagoner Road (#5350) was installed in 1982 at the same site as a stream flow gage station (FCDMC, 2001).

1.3 Hydrology

The Hassayampa River watershed (HUC#15070103-007) drains approximately 220 square miles with an overall drop in elevation of 4,050 ft. This reach of the Hassayampa River includes both perennial and intermittent flow regimes; most of its tributaries are ephemeral.

Hassayampa Lake (HUC#AZL15070103-3160) is located near the headwaters of the Hassayampa River drainage and has an approximate surface area of two acres. It was formed by a concrete impoundment across the Hassayampa River. In wet years, the lake level overflows the dam spillway and provides flow to the Hassayampa River. At the bottom of the dam, a leaky 12-inch diameter pipeline provides continual flow to the Hassayampa River. This pipe once carried water from Hassayampa Lake to a reservoir for Prescott, where it was retained as reserve for fire protection. That water right has been sold and the pipeline abandoned. The lake is now privately owned.

Stream channels are deeply incised in the steep upland areas of HUC#15070103-007A. Streamflow is dominated by spring runoff and summer monsoons and disappears completely during the early summer months (DBSA, 1990). Except for a few perennial stretches receiving constant discharge from Hassayampa Lake, springs, or adits, flow on this segment of the Hassayampa River is intermittent.

In the lower portion of the watershed, stream channels are more gently sloped, and the river lies in a flood plain 500 to 1,000 ft wide. Flow in this segment is intermittent and sustained by groundwater discharge. On this stretch of the Hassayampa River, the FCDMC installed stream flow gage station #5353 on Wagoner Road which has been in operation from 1991 until present (FCDMC, 2001). Near this location, two historical U.S. Geological Survey (USGS) gage stations have collected river stage data. The USGS gage station near Wagoner (#09514500) has a period of record from 1940 to 1946, while the USGS gage station at Walnut Grove near Wagoner (#09515000) has a period of record from 1912 to 1915, 1917 to 1918, and 1980 to 1983 (USGS, 2001).

1.4 Geology

The upper Hassayampa River watershed lies in the Bradshaw Mountains which consist primarily of early Proterozoic metavolcanic and metasedimentary rocks

intruded by Proterozoic granitic to tonalitic plutons. They are intruded and overlain by Tertiary andesite and Tertiary to Quaternary basalt, primarily in the central and western portions of the watershed (Figure 2).

Mining for ore rich in copper, zinc, lead, silver, and gold, along with iron, arsenic, cadmium, and other metals, began in the Bradshaw Mountains in the mid-1880s. Most of the mines are located in a belt of Yavapai Schist that includes sericitic, chloritic, and amphibolitic schists (DBSA, 1990). The schists are intruded by several smaller masses of diorite or gabbro (Lindgren, 1926). Most of the deposits in Hassayampa mining district consist of Mesozoic or early Tertiary deposits (Wilson, et. al., 1934). Their ore shoots contain abundant sulfides, principally pyrite, galena, sphalerite, chalcopyrite, arsenopyrite, hematite, and magnetite. Most of the gold occurs as submicroscopic intergrowths within the sulfides, particularly the fine grained galena, chalcopyrite, and pyrite (Wilson, et. al., 1934).

The Bradshaw and Weaver Mountains are separated by a north-northwest trending valley filled with Tertiary to Quaternary sandstone and conglomerate. The downstream segment of the Hassayampa River (HUC#15070103-007B) flows over the gentle slopes and pediments formed by the sandstone and conglomerate. These sedimentary deposits are up to 135 ft thick near Wagoner, and they overlie bedrock (Sanger and Appel, 1980).

Basin fill is the youngest geologic unit in the area and is composed mainly of unconsolidated gravel and sand with significant quantities of boulders, cobbles, silt and clay. The unit serves as a conduit for direct runoff that infiltrates readily through the gravel and sand that form the channel bottoms and flood plains of the stream and washes.

1.5 Vegetation/Wildlife

The vegetation of the upper Hassayampa River watershed is highly dependent on elevation and the corresponding variations in precipitation and temperature. The uplands area, in the Prescott National Forest, consists of ponderosa pine forests. Between elevations of 5,000 to 7,000 ft msl lie the pinyon-juniper woodlands. Along the flanks of the mountain ranges below 5,000 ft msl, the vegetation consists primarily of chaparral shrublands and grasses grading into semidesert vegetation below. Wildlife in the area include deer, javelina, small mammals, and birds including spotted owls (DBSA, 1990).

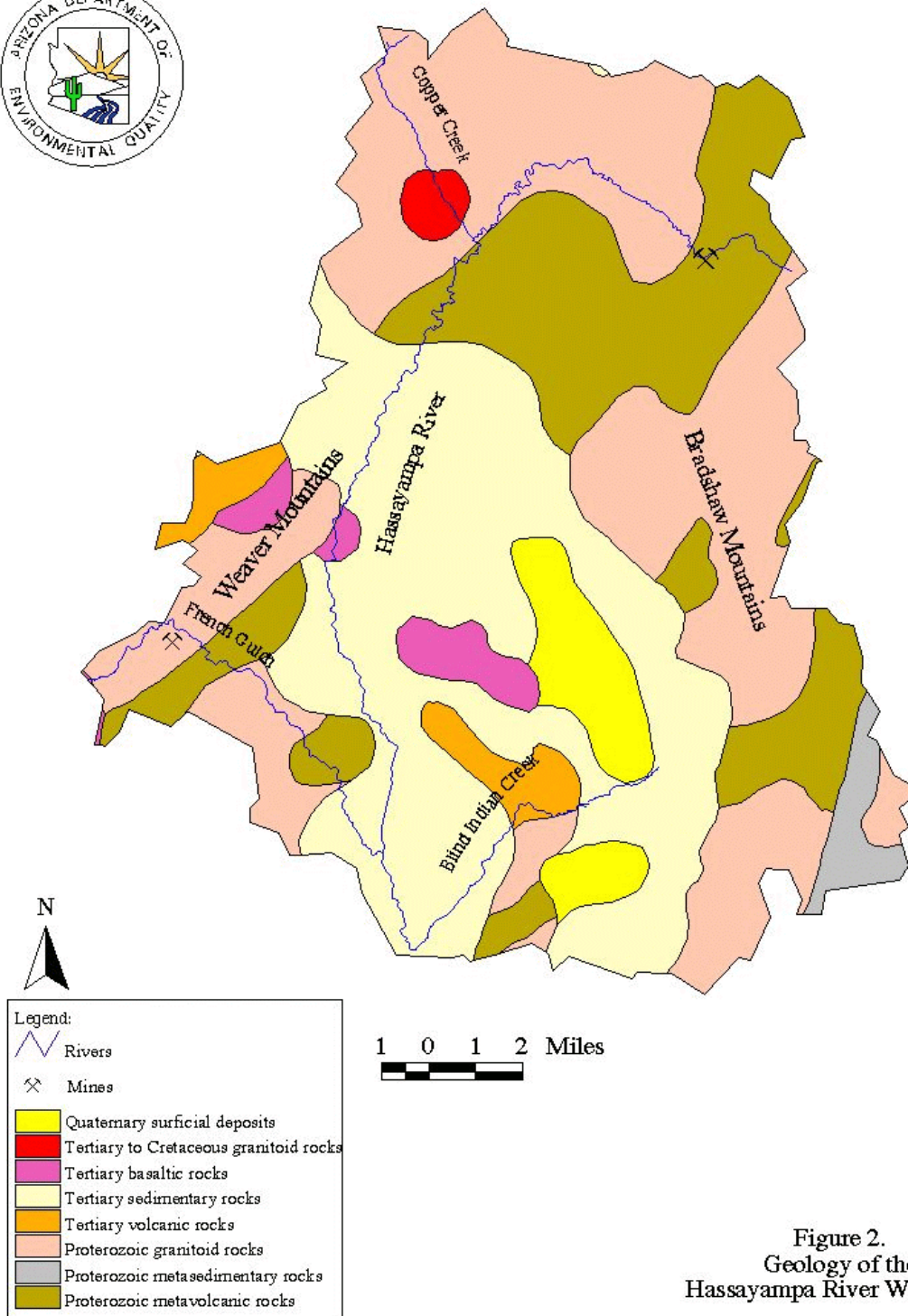


Figure 2.
Geology of the
Hassayampa River Watershed

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1.6 Land Use

The bulk of the watershed lies in the Bradshaw Ranger District of the Prescott National Forest. Within the National Forest, land uses include recreation, timber harvesting, grazing, mining, and wildlife. Private land exists in the upstream reach as patented claims, historic town sites, and residential property.

Public and private lands also border HUC#15070103-007B. In this portion of the watershed, cattle ranching is the predominant land use. The Zonia Mine, inactive since 1975, is located on French Gulch within the lower Hassayampa River watershed.

2.0 NUMERIC TARGETS

2.1 Clean Water Act Section 303(d) List

Section 303(d) of the Clean Water Act requires states to compile a list of surface waterbodies that do not meet applicable water quality standards. TMDLs must be developed for every waterbody on the 303(d) List. TMDLs set the amount of given pollutant(s) that the waterbody can withstand without creating an impairment of that surface water's designated use(s).

The Hassayampa River from its headwaters to its confluence with Blind Indian Creek (HUC#15070103-007) was included by the State of Arizona on its 1998 303(d) List for the non-attainment of dissolved cadmium, copper, and zinc water quality standards. The listing was based on 14 samples collected by ADEQ and U.S. Forest Service (USFS) in the Senator Mine area between water years (WY) 1991 and 1993. Monitoring performed by the ADEQ Bioassessment and Fixed Station Network (FSN) Programs between WY1991 and 1996 yielded an additional 27 samples (ADEQ, 2000). These data are summarized in Appendix A. Two other reaches of the Hassayampa River are on the 303(d) List (ADEQ, 1998) (HUC#15070103-001B for chlordane, DDT metabolites, dieldrin, and toxaphene; and HUC#15070103-004 for turbidity) but are not included in these TMDLs. French Gulch (HUC#15070103-239) is an ephemeral tributary to this reach of the Hassayampa River and is also included on Arizona's 1998 303(d) List for cadmium, copper, manganese, pH, and zinc. It will be addressed in a separate TMDL analysis.

2.2 Beneficial Use Designations

ADEQ codifies water quality regulations in Title 18, Chapter 11 of the Arizona

Administrative Code (A.A.C.) (ADEQ, 1996). Designated beneficial uses, such as consumption, recreation, agriculture, and aquatic biota, are described in Section R18-11-104 of the A.A.C. and are listed for specific surface waters in Appendix B of A.A.C. R18-11. The Hassayampa River is currently protected along reach HUC#15070103-007 for the following designated uses: Aquatic and Wildlife warm water fishery (A&Ww), Fish Consumption (FC), Full Body Contact (FBC), Agricultural Livestock Watering (AgL), and Agricultural Irrigation (AgI). The stream was assessed as in non-attainment of the A&Ww designated use.

Upon segmentation of the reach at the confluence of Copper Creek, the sub-reach above 5,000 ft msl, from the headwaters to Copper Creek (HUC#15070103-007A), will be protected with the Aquatic and Wildlife cold water (A&Wc), FC, FBC, AgL, and AgI designated uses, while the sub-reach below 5,000 ft msl, from Copper Creek to Blind Indian Creek (HUC#15070103-007B), will be protected by the A&Ww, FC, FBC, AgL, and AgI designated uses (ADEQ, 2002b).

2.3 Applicable Water Quality Standards

Water quality standards are adopted by states and tribes to maintain and restore waterbodies for designated beneficial uses as described in the preceding section. These surface water quality standards are defined in Appendix A of A.A.C. R18-11 (ADEQ, 1996) and can be expressed either as numeric values (e.g., contaminant concentrations) or narrative statements (e.g., “A surface water shall be free from ...”).

The State of Arizona has established numeric water quality standards to protect the aforementioned designated uses for the Hassayampa River (HUC#15070103-007). The standards for the FC, FBC, AgL, and AgI designated uses for the listed metals are presented in Table 1.

Table 1. FC, FBC, AgL, and AgI Numeric Standards.

	FC Standard (µg/L)	FBC Standard (µg/L)	AgL Standard (µg/L)	AgI Standard (µg/L)
Cadmium	41 T	70 T	50 T	50 T
Copper	NNS	5,200 D	500 T	5,000 T
Zinc	22,000 T	42,000 T	25,000 T	10,000 T

µg/L = micrograms per liter
NNS = no numeric standard

T = total recoverable
D = dissolved

Aquatic and Wildlife standards may be classified as acute exposure, the level of a contaminant that causes toxic impacts in organisms with a short exposure, or chronic exposure, a lower level that may cause toxic impacts based on a longer exposure period (ADEQ, 2000). Because the chronic exposure standards are the more stringent standards, they are the standards which serve as numeric targets for TMDL calculation.

The A&Ww standards for dissolved cadmium, copper, and zinc are hardness-dependent. Equations to compute the applicable standards are provided in Appendix A, Table 2 (footnotes c, e and j) of A.A.C. R18-11 (ADEQ, 1996) and are presented in the table below. For these equations, sample hardness is calculated by the laboratory and may not exceed 400 mg/L CaCO₃.

Table 2. A&Ww Numeric Standards

	A&Ww chronic exposure Standard (µg/L)
Cadmium, dissolved	$e^{(0.7852[\ln(\text{Hardness})]-3.490)}$
Copper, dissolved	$e^{(0.8545[\ln(\text{Hardness})]-1.465)}$
Zinc, dissolved	$e^{(0.8473[\ln(\text{Hardness})]+0.761)}$

ADEQ considers revisions to the surface water quality standards every three years. In the current triennial review process, changes have been proposed to the A&W standards for cadmium, copper, and zinc (ADEQ, 2002a). In anticipation of the changes in designated uses, both the A&Ww and the A&Wc proposed standards are presented in Table 3.

Table 3. Proposed A&W Numeric Standards

	Proposed A&Ww chronic exposure Standard (µg/L)	Proposed A&Wc chronic exposure Standard (µg/L)
Cadmium, dissolved	$e^{(0.7852[\ln(\text{Hardness})]-2.715)*(1.101672-[\ln(\text{Hardness})]*0.041838)}$	$e^{(0.7852[\ln(\text{Hardness})]-2.715)*(1.101672-[\ln(\text{Hardness})]*0.041838)}$
Copper, dissolved	$e^{(0.8545[\ln(\text{Hardness})]-1.702)*(0.96)}$	$e^{(0.8545[\ln(\text{Hardness})]-1.702)*(0.96)}$
Zinc, dissolved	$e^{(0.8473[\ln(\text{Hardness})]+0.433)*(0.986)}$	$e^{(0.8473[\ln(\text{Hardness})]+0.884)*(0.986)}$

The determination of compliance was conducted in accordance with current standards; however, the proposed changes will result in more stringent copper

standards and less stringent cadmium and zinc standards. In anticipation of these changes, an implicit margin of safety has been incorporated by calculating the TMDLs using the current and the proposed changes, so that the adoption of the proposed standards and designated uses will not result in the reach being re-listed.

3.0 SOURCE ASSESSMENT

The data used to determine impairment for the 303(d) listing were collected during the 1990s in support of the goals of other programs and, as such, are insufficient to isolate sources or to calculate TMDLs. As part of this project, the ADEQ TMDL Program collected data specific to the goals of source identification and TMDL calculation.

A site visit in February 2000 by personnel from ADEQ, USFS, and US EPA laid the groundwork for a watershed wide sampling effort undertaken by the ADEQ TMDL Program from September 2000 through August 2001. The sampling effort Project Plan is attached in Appendix B. Water quality samples were collected on a monthly to bimonthly frequency at 14 sites to systematically monitor conditions along the listed reach. Due to the intermittent nature of the reach, not every site was sampled during each sampling event. Sites were established at the beginning and end of the reach; upstream and downstream of potential non point sources; at potential point sources; and at easily accessible monitoring locations. Hassayampa Lake was not sampled, but sites upstream and downstream of the lake were sampled. Site locations are listed in the Project Plan and are presented on Figures 3a and 3b.

The results of the sampling effort demarcated a stretch of approximately two stream miles of observed impairment in the upper reaches of the watershed. The majority of exceedances occurred downstream of the Wetlands tailings piles; downstream of the confluence of Maple Gulch tributary (where the McClellan tailings piles are located); and downstream of the Senator Gold Mine tailings piles and from the adit discharge. Although metals concentrations are attenuated at site MGHSR108.17, they still often exceed dissolved cadmium, copper and zinc standards. At site MGHSR104.90, the waterbody is back into compliance. Exceedances of applicable standards were not observed in the downstream stretch (HUC#15070103-007B) of the listed reach. The results from the ADEQ TMDL sampling effort are presented in Appendix C.

Low pH values are often associated with dissolved metal impairments, and indeed, pH values outside the standard range of 6.5 to 9.0 SU were observed in the impaired stretch. However, HUC#15070103-007 is not currently included on Arizona's 303(d) List for pH impairment. The Arizona Revised Statutes (2000) prohibit development of TMDLs for parameters not included on the List, so no TMDL was calculated for pH. An implementation plan to reduce the metals loading will result in a reduction of pH loading.

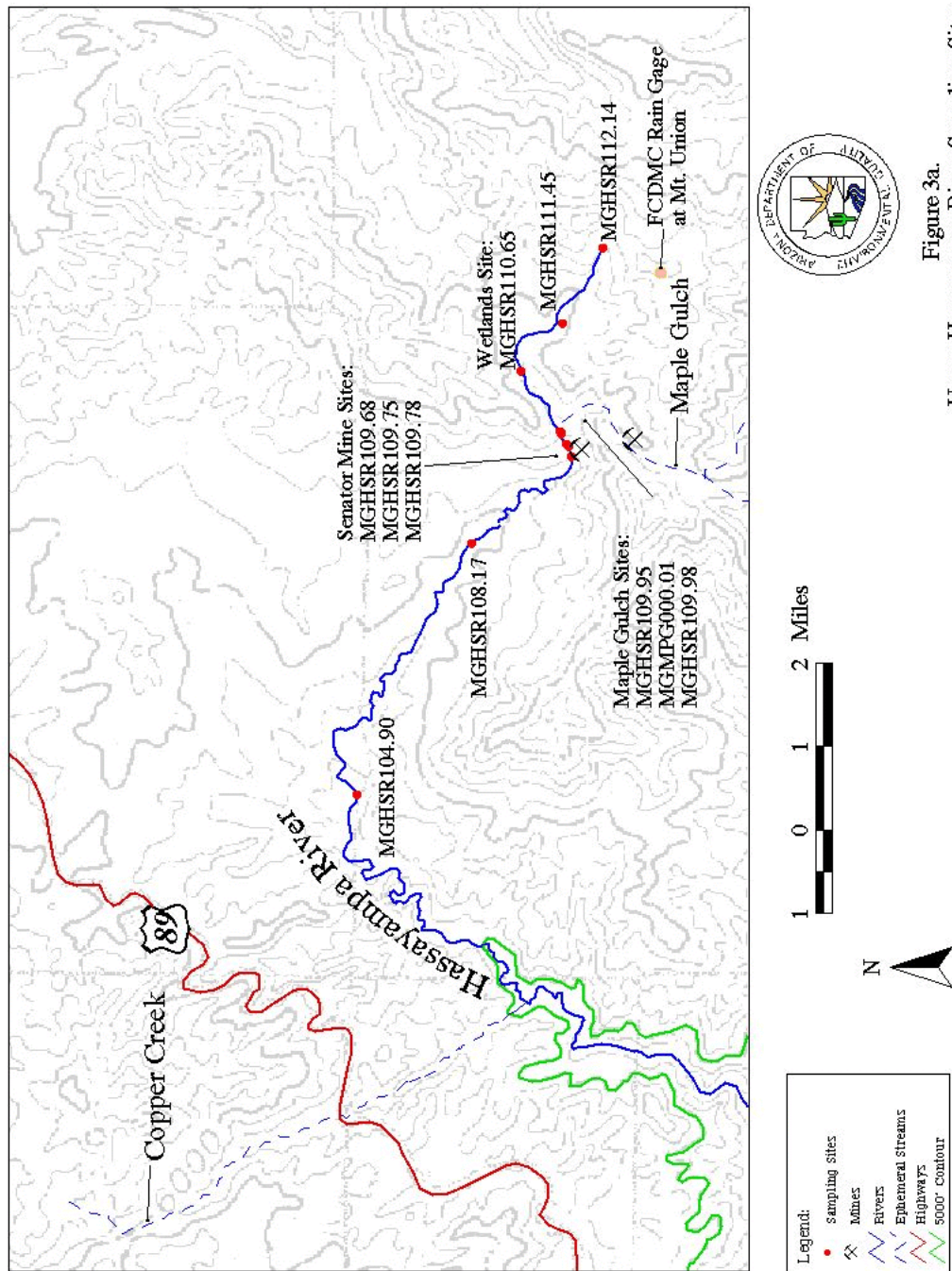
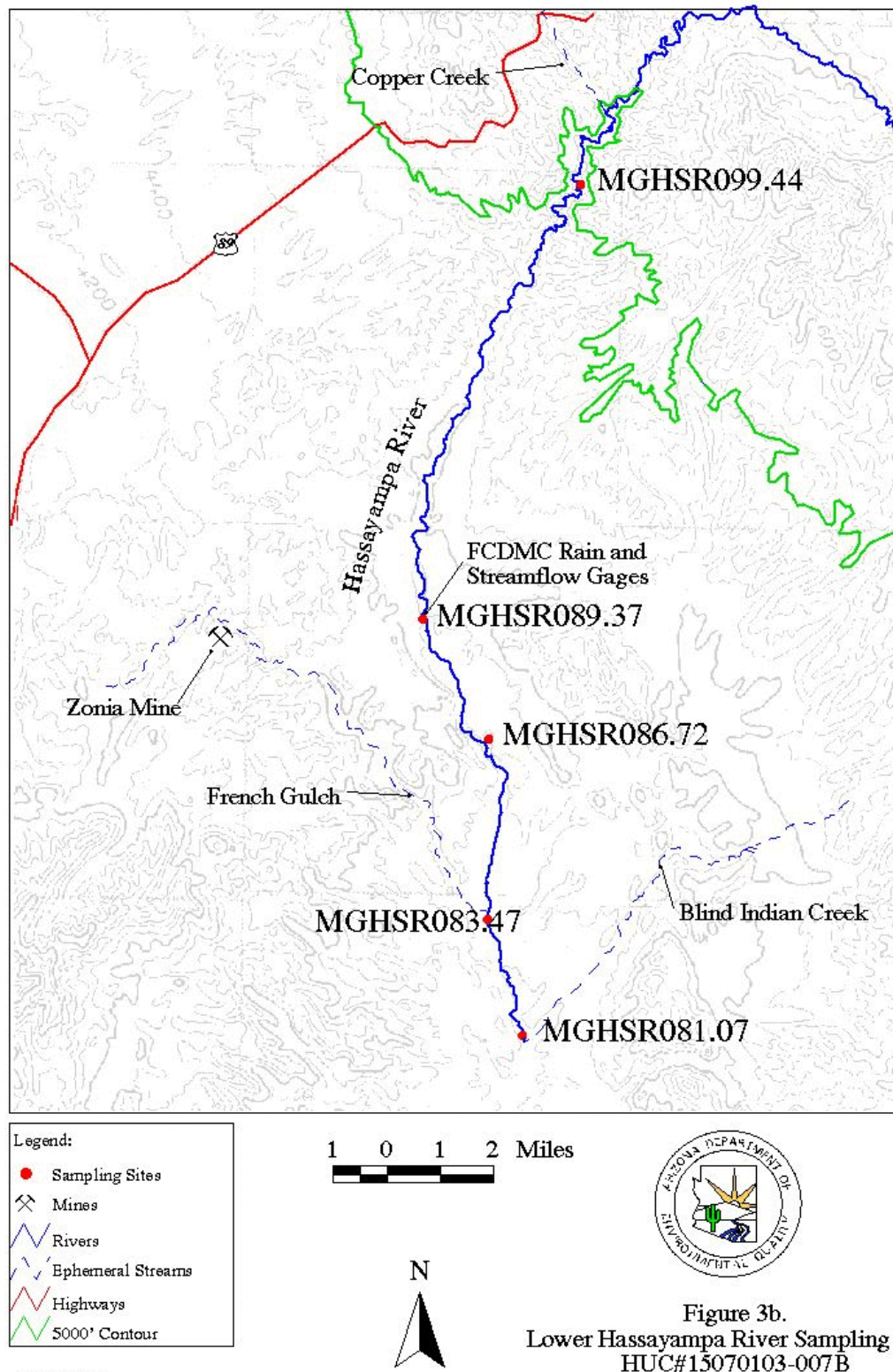


Figure 3a.
Upper Hassayampa River Sampling Sites
HUC#15070103-007A

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3.1 Wetlands Tailings Pile

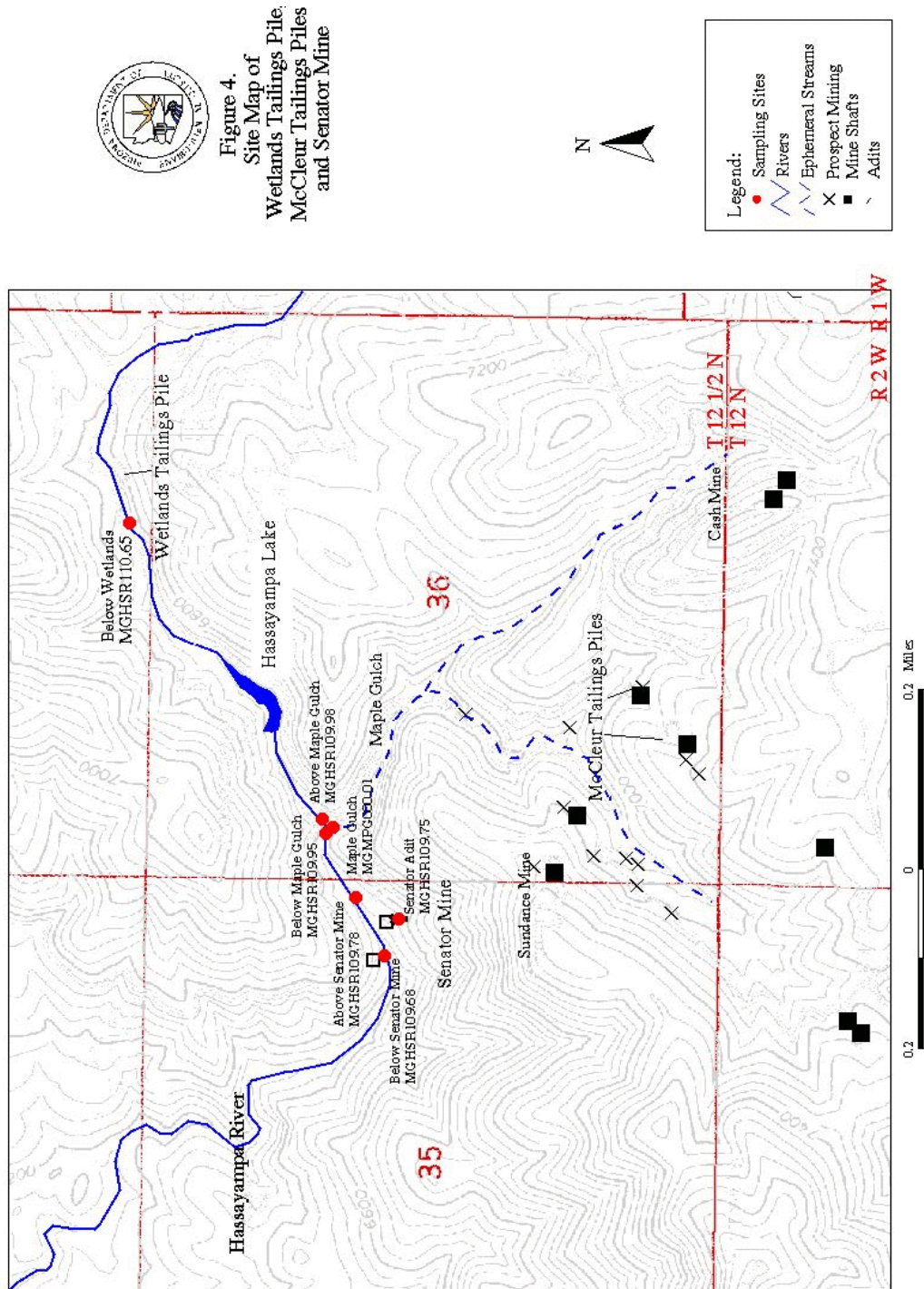
A tailings pile with a surface area of 1,746 square yards is located in Section 25, Township 12½ N, Range 2 W (Weston, 2002). In this document the tailings pile is referred to as the Wetlands tailings pile, although it is also called the McKinley Mill. The tailings pile lies immediately adjacent to the stream bed with the toe of the tailings in the channel. The ownership of the property is being determined; possible owners include the Prescott National Forest, the City of Prescott, and private landowners. ADEQ established a sampling site downstream of the tailings pile (site MGHSR110.65) (Figure 4).

3.2 Maple Gulch Drainage (McCleur Tailings Piles)

The McCleur tailings piles are located in Section 36, Township 12½ N, Range 2 W and consist of approximately 150,000 cubic yards of fine-grained tailings (DBSA, 1990) situated in a relatively flat valley bottom on National Forest land. Two drainages cross the tailings area: one, from the vicinity of the Sundance Mine, and a second from the Cash Mine area. These drainages join to form the Maple Gulch tributary which flows 0.33 miles to its confluence with the Hassayampa River. Sampling sites were established upstream (site MGHSR109.98), downstream (site MGHSR109.95), and at the confluence (site MGMPG000.01) of Maple Gulch (Figure 4). In the Maple Gulch drainage, there are multiple point and non point sources. The sample site at the confluence can only serve to characterize the entire drainage and cannot determine what quantity of loads each of the abandoned mines and tailings piles is contributing to the Maple Gulch loads to the Hassayampa River.

3.3 Senator Gold Mine

The Senator Gold Mine is located on private land in Section 35, Township 12½ N, Range 2 W. The site includes the mine adit, a point source, and a tailings pile, a non point source. (A NPDES permit was issued for the adit discharge from 1978 to 1983 but was not renewed. Although there is not a current NPDES permit for this discharge, it is a discrete conveyance and is considered a point source for the purpose of these TMDLs.) The tailings pile is approximately 120,000 cubic yards (DBSA, 1990) and is located below the adit on a steep slope above the Hassayampa River. Perennial drainage at a constant average rate of 0.063 cubic feet per second (cfs) flows from the mine adit across the tailings to the Hassayampa River. Precipitation events do not affect this rate of discharge. The ADEQ TMDL program established sampling sites upstream (site MGHSR109.78), and downstream (site MGHSR109.68) to bracket the tailings pile, and at the adit (site MGHSR109.75) (Figure 4).



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3.4 Other Potential Sources

Zonia Mine is an inactive mine located on private land in the upper reaches of French Gulch (Sections 11, 12, 13, and 14, Township 11 N, Range 4 W) and is regulated under the Arizona Aquifer Protection Program. Seeps and springs near the Zonia Mine sometimes exceed the pH standard, the Partial Body Contact (PBC) standard for total manganese, and the A&W ephemeral (A&We) standards for cadmium, copper, and zinc. A sampling site (site MGHSR083.47) was established on the Hassayampa River downstream of the confluence of French Gulch; however, due to the ephemeral nature of French Gulch, contributing flow from French Gulch to the Hassayampa River was not observed during the sampling effort.

Numerous other historic mine shafts and smaller tailings piles exist in the watershed. As potential sources, ADEQ believes that these contribute minor loadings compared to the magnitude of dissolved cadmium, copper, and zinc loading from the Wetlands tailings pile, Maple Gulch drainage (McClellan tailings piles), and the Senator Mine adit and tailings pile.

No NPDES permitted point sources currently exist in the watershed of HUC#15070103-007.

4.0 TMDL CALCULATIONS

A TMDL is comprised of load allocations (LAs) for natural background loads and nonpoint sources, and wasteload allocations (WLAs) for point sources for a given waterbody. In addition, the TMDL must include a margin of safety (MOS) to account for any uncertainties in TMDL analysis. The sum of these components may not exceed the TMDL, conceptually denoted by the equation:

$$\text{TMDL} = \sum \text{LAs} + \sum \text{WLAs} + \text{MOS} \quad (\text{US EPA, 1999})$$

Only reasonably current, credible, and scientifically defensible data can be used in TMDL development (ARS, 2000). The use of historic water quality data was considered, however, these data were disregarded because 1) it was unclear whether lab data referred to total or dissolved metals concentrations, 2) the data lacked corresponding instantaneous flow measurements necessary to calculate loads, or 3) the data lacked sample hardness values necessary to calculate applicable standards. Data used in the calculation of the TMDLs were collected during spring, summer, fall, and winter in order to ensure consideration of any potential seasonal variation in the system.

Loads were calculated by multiplying the flow-weighted average or representative metal

concentration ($\mu\text{g/L}$) by the flow rate (cfs) and a unit conversion factor ($k=0.002445$) to convert $\mu\text{g/L}$ and cfs to kilograms per day (kg/day):

$$\text{load (kg/day)} = \text{concentration } (\mu\text{g/L}) \times \text{flow (cfs)} \times k$$

Tables 4a - 4d. Load and Wasteload Calculations

Table 4a. Wetlands Tailings Pile Load Calculations

Q (cfs)	Hardness (mg/L)	Dissolved Metal	Natural Background		Downstream of Wetlands		Measured Load (kg/day)
			Conc. ($\mu\text{g/L}$)	Load (kg/day)	Conc. ($\mu\text{g/L}$)	Load (kg/day)	
0.15	108	Cadmium	2.5	0.001	3	0.001	0
0.15	108	Copper	7.5	0.003	35	0.013	0.010
0.15	108	Zinc	20	0.007	130	0.046	0.039
3.97	28	Cadmium	2.5	0.024	2.5	0.024	0
3.97	28	Copper	7.5	0.073	38	0.369	0.296
3.97	28	Zinc	20	0.194	40	0.388	0.194

Table 4b. Senator Gold Mine Tailings Pile Load Calculations

Q (cfs)	Hardness (mg/L)	Dissolved Metal	Upstream of Senator		Downstream of Senator		Measured Load (kg/day)
			Conc. ($\mu\text{g/L}$)	Load (kg/day)	Conc. ($\mu\text{g/L}$)	Load (kg/day)	
0.11	251	Cadmium	5	0.001	19	0.005	0.004
0.11	251	Copper	227	0.062	52	0.014	0
0.11	251	Zinc	329	0.090	1892	0.518	0.428
5.4	60	Cadmium	2.5	0.033	8	0.106	0.073
5.4	60	Copper	296	3.908	315	4.159	0.251
5.4	60	Zinc	450	5.941	720	9.509	3.565

Table 4c. Maple Gulch Drainage Wasteload Calculations

Q (cfs)	Hardness (mg/L)	Dissolved Metal	Concentration (µg/L)	Measured Load (kg/day)
0.238	219	Cadmium	25.2	0.015
0.238	219	Copper	2122.9	1.235
0.238	219	Zinc	1962	1.142

Table 4d. Senator Gold Mine Adit Wasteload Calculations

Q (cfs)	Hardness (mg/L)	Dissolved Metal	Concentration (µg/L)	Measured Load (kg/day)
0.063	400	Cadmium	51.7	0.008
0.063	400	Copper	13.1	0.002
0.063	400	Zinc	5097	0.785

The current and proposed Allocations were subtracted from the Measured Loads to calculate the Load Reductions. If the resultant values were positive, Load Reductions were required; if the values were negative, no Load Reductions are necessary, and zeroes were entered in the spreadsheet. Tables 5 and 6 present the calculations.

Tables 5a - 5d. TMDLs and Allocations based on Current Standards

Table 5a. Wetlands Tailings Pile TMDLs and Load Allocations based on Current Standards

Q (cfs)	Dissolved Metal	A&Ww Standard (µg/L)	TMDL (kg/day)	Allocation (kg/day)	Measured Load (kg/day)	Load Reduction (kg/day)
0.15	Cadmium	1.2	0	0	0	0
0.15	Copper	12.6	0.004	0.004	0.010	0.006
0.15	Zinc	113.1	0.040	0.036	0.040	0.004
3.97	Cadmium	0.4	0.004	0.004	0	0
3.97	Copper	4.0	0.039	0.035	0.296	0.261
3.97	Zinc	36.0	0.350	0.315	0.194	0

Table 5 b. Senator Mine TMDLs and Load Allocations based on Current Standards

Q (cfs)	Dissolved Metal	A&Ww Standard (µg/L)	TMDL (kg/day)	Allocation (kg/day)	Measured Load (kg/day)	Load Reduction (kg/day)
0.11	Cadmium	2.3	0.001	0.001	0.004	0.003
0.11	Copper	26.0	0.007	0.006	0	0
0.11	Zinc	231.1	0.063	0.057	0.420	0.363
5.4	Cadmium	0.8	0.010	0.009	0.073	0.064
5.4	Copper	7.6	0.101	0.091	0.251	0.160
5.4	Zinc	68.7	0.907	0.817	3.565	2.748

Table 5c. Maple Gulch Drainage TMDLs and
Wasteload Allocations based on Current Standards

Q (cfs)	Dissolved Metal	A&Ww Standard (µg/L)	TMDL (kg/day)	Allocation (kg/day)	Measured Load (kg/day)	Load Reduction (kg/day)
0.238	Cadmium	2.1	0.001	0.001	0.015	0.014
0.238	Copper	23.1	0.013	0.012	1.235	1.223
0.238	Zinc	206.2	0.120	0.108	1.142	1.034

Table 5d. Senator Mine Adit TMDLs and Wasteload Allocations based on Current Standards

Q (cfs)	Dissolved Metal	A&Ww Standard (µg/L)	TMDL (kg/day)	Allocation (kg/day)	Measured Load (kg/day)	Load Reduction (kg/day)
0.063	Cadmium	3.4	0.001	0	0.008	0.007
0.063	Copper	38.7	0.006	0.005	0.002	0
0.063	Zinc	342.9	0.053	0.048	0.785	0.738

Tables 6a - 6d. TMDLs and Allocations based on Proposed Standards

Table 6a. Wetlands Tailings Pile TMDLs and Load Allocations based on Proposed Standards

Q (cfs)	Dissolved Metal	A&Wc Standard (µg/L)	TMDL (kg/day)	Allocation (kg/day)	Measured Load (kg/day)	Load Reduction (kg/day)
0.15	Cadmium	2.4	0.001	0.001	0	0
0.15	Copper	9.6	0.003	0.003	0.010	0.007
0.15	Zinc	126.1	0.045	0.042	0.039	0
3.97	Cadmium	0.9	0.008	0.007	0	0
3.97	Copper	3.0	0.029	0.026	0.296	0.270
3.97	Zinc	40.2	0.390	0.351	0.194	0

Table 6b. Senator Mine TMDLs and Load Allocations based on Proposed Standards

Q (cfs)	Dissolved Metal	A&Wc Standard (µg/L)	TMDL (kg/day)	Allocation (kg/day)	Measured Load (kg/day)	Load Reduction (kg/day)
0.11	Cadmium	4.4	0.001	0.001	0.004	0.003
0.11	Copper	19.7	0.005	0.005	0	0
0.11	Zinc	257.7	0.071	0.064	0.428	0.364
5.4	Cadmium	1.5	0.020	0.018	0.073	0.055
5.4	Copper	5.8	0.076	0.068	0.251	0.183
5.4	Zinc	76.6	1.012	0.911	3.565	2.654

Table 6c. Maple Gulch TMDLs and Wasteload Allocations based on Proposed Standards

Q (cfs)	Dissolved Metal	A&Wc Standard (µg/L)	TMDL (kg/day)	Allocation (kg/day)	Measured Load (kg/day)	Load Reduction (kg/day)
0.238	Cadmium	4.0	0.002	0.002	0.015	0.013
0.238	Copper	17.5	0.010	0.009	1.235	1.226
0.238	Zinc	229.5	0.134	0.120	1.142	1.022

Table 6d. Senator Mine Adit TMDLs and Wasteload Allocations based on Proposed Standards

Q (cfs)	Dissolved Metal	A&Wc Standard (µg/L)	TMDL (kg/day)	Allocation (kg/day)	Measured Load (kg/day)	Load Reduction (kg/day)
0.063	Cadmium	6.2	0.001	0.001	0.008	0.007
0.063	Copper	29.3	0.005	0.004	0.002	0
0.063	Zinc	382.4	0.059	0.053	0.785	0.732

4.1 Critical Conditions and Flows

Because loads are calculated by multiplying a pollutant concentration by flow,

critical condition(s) or flow(s) must be specified before a TMDL is calculated. The Hassayampa River TMDLs have been calculated based on real loads at low flow and spring runoff critical conditions.

4.1.1 Low Flow

Low flow was not further defined as “baseflow” or “7Q10” flow because of the lack of the necessary gage data. Furthermore, in the case of ephemeral and intermittent segments, baseflow and 7Q10 flow equal zero. When low flow conditions exist in the Hassayampa River, the Maple Gulch tributary and Senator Mine adit discharge are the primary sources of water and pollutant loads to the river.

To calculate Load Allocations for this critical condition, the average flow at the site downstream of the non point source was used; the average flow of the point source was used for Wasteload Allocations. Flow weighted averaging was applied to calculate average hardness and metals concentration values using the following equation in which C is concentration (mg/L or µg/L) and Q is flow (cfs):

$$C = \frac{\sum_{i=1}^n (C_i * Q_i)}{\sum_{i=1}^n Q_i}$$

4.1.2 Spring Runoff

Spring runoff was identified as a second critical condition. In an average year, the snowpack lies on the tailings piles from approximately November through March, so that the tailings piles are saturated at the time of spring runoff. One representative spring runoff data set was collected on March 23, 2001. This data set included flows of the Hassayampa River at the Wetlands, Maple Gulch, and Senator Mine sites ranging from 3.97 cfs to 5.40 cfs. The concentration and flow values from this event were used directly to calculate the Measured Loads for the spring runoff critical condition.

4.2 Total Maximum Daily Loads

TMDLs were calculated by multiplying the most stringent water quality standard for the pollutant of concern by the critical flows and a unit conversion factor (k). Both the current and the proposed A&W chronic exposure standards were used to calculate the TMDLs. The flow weighted average hardness of the Hassayampa River downstream of the non point source or at the point source was used to calculate the applicable standards and then derive the TMDLs.

4.3 Load Allocations

The flow and hardness of the site downstream of the non point source were used to calculate the TMDLs. The Measured Loads for non point sources were calculated by subtracting the Load_{upstream} from the Load_{downstream}.

4.3.1 Natural Background

Average natural background concentrations were calculated from samples collected at the headwaters and 0.69 miles downstream of the headwaters (sites MGHSR112.14 and MGHSR111.45) which drain a subbasin of the upstream reach. Although there is evidence of historic mining near these sites (an arrastre near the spring at the headwaters and adits near the stream), applicable metals standards were not exceeded at either site. pH measurements were often below the standard of 6.5 SU; however, the reach has not been identified as impaired for pH on the 303(d) List. Any implementation to decrease metals loading will also eliminate pH exceedances. Because dissolved cadmium and copper were not detected in any of the five samples collected, average concentrations were defaulted to half of the detection limit (ADEQ, 2002c). Dissolved zinc was detected at these sites at concentrations up to 30 µg/L. Based on these sample data, the background concentrations of cadmium, copper, and zinc were calculated as 2.5, 7.5, and 20 µg/L respectively. These natural background loads were only included in the calculations for the Wetlands source. At the Senator tailings piles, they were not included in the calculations because the load_{upstream} was subtracted from the load_{downstream}, in effect, zeroing the load immediately upstream of the source.

4.3.2 Wetlands Tailings Pile

Samples collected below the Wetlands site rarely exceed cadmium, occasionally exceed pH standards, and always exceed copper and zinc standards. The Measured Loads were calculated by subtracting the natural background loads from the load_{downstream}.

4.3.3 Senator Mine Tailings Pile

The sample site upstream of Senator Mine (site MGHSR109.78) is 0.17 miles downstream from the site downstream of Maple Gulch (site MGHSR109.95). No sources were observed between these two sites, and except for some attenuation, the water quality does not change significantly between the two sites (Appendix C). Therefore, the site upstream of Senator Gold Mine exceeds copper and zinc standards due to loading from the Maple Gulch Drainage. The Measured Loads were calculated by subtracting the Load_{upstream} from the Load_{downstream}.

4.4 Wasteload Allocations

The point sources do not have critical flows associated with them; their discharges are relatively constant. Measured Loads from point sources were calculated by averaging the load entering the Hassayampa River. TMDLs were calculated using hardness values of the receiving water at the site immediately downstream of the point source.

4.4.1 Maple Gulch Drainage (McCleure Tailings Piles)

In the Maple Gulch drainage, there are multiple possible point and non point sources. ADEQ site MGMPG000.01 was located on Maple Gulch approximately 20 feet (ft.) upstream of its confluence with the Hassayampa River. Because these samples only represent the contribution of the entire Maple Gulch drainage, the allocation cannot be further subdivided to individual tailings piles.

This tributary is the largest source of cadmium, copper, and zinc, mostly in the dissolved form. All of the samples taken from Maple Gulch (site MGMPG000.01) exceeded the A&Ww standards for dissolved copper and dissolved zinc, and the AgL standard for total copper. The Maple Gulch stream water generally has a pH of less than 4 SU. At the confluence, in the mixing zone, in-stream indicators include a white precipitate in the bed rock channel. Immediately downstream of the Maple Gulch confluence (site MGHSR109.95), samples exceed cadmium, copper, zinc, and pH standards, but attenuation is observed.

4.4.2 Senator Mine Adit

Samples taken of the Senator Mine adit discharge (site MGHSR109.75) have dissolved zinc and dissolved cadmium in excess of A&Ww standards, total cadmium in excess of FC standards, and concentrations of dissolved copper generally within standards. One exceedance of total zinc was measured. This adit is the richest source of cadmium and zinc, but the average discharge is only 0.063 cfs. The pH of this adit discharge has been neutralized as it flows over calcareous amphibolite in the mine shaft. The hardness of the adit discharge was generally greater than 400 mg/L, so the maximum value of 400 mg/L was used to calculate the TMDLs.

4.5 Margin of Safety

Section 303(d) of the Clean Water Act requires that TMDLs be established with a MOS to account for uncertainties in the relation between pollutant loads and the quality of the receiving water body. There are two basic methods for incorporating the MOS: explicitly specifying a portion of the total TMDL as the MOS; or implicitly incorporating the MOS using conservative assumptions to develop allocations.

4.5.1 Explicit Margin of Safety

An explicit MOS was applied to the Hassayampa River TMDLs to account for uncertainties such as laboratory and analysis error, uncertainties in the numeric standards/targets, uncertainties in the source analysis, and uncertainties in the relation between pollutant loads and flow. This conservative MOS has been applied by multiplying the TMDLs by 90%, thereby decreasing the TMDLs by 10%.

4.5.2 Implicit Margin of Safety

An additional implicit MOS was incorporated in the TMDL analysis based on the following conservative considerations:

- a) anticipated changes to designated uses and standards will result in more stringent cadmium and copper standards;
- b) the sample hardness values of spring runoff critical condition were low, resulting in more stringent standards than a rainfall/runoff event;
- c) the TMDLs are based on chronic exposure standards.

5.0 IMPLEMENTATION AND MONITORING

These TMDLs are being developed under a phased approach. This document represents the first phase of an overall effort to bring the surface waters of the Hassayampa River into compliance. This phase was designed to verify the water quality concerns, to identify sources of pollution, to determine the water quality goals in the subwatershed, and to recommend actions to reduce pollutant loading. The second phase is intended to reduce the uncertainties in these TMDLs by collecting additional data needed to refine source identification, critical flow conditions, and loading, and expanding on the implementation plan.

The U.S. Environmental Protection Agency (US EPA) has been assessing abandoned mine sites in the Hassayampa River watershed. Senator Mine, the McClell Tailings, and Cash Mine are on the Comprehensive Environmental Response, Compensation, and Liability Information System (CERCLIS). The Preliminary Assessment (PA) documentation is on-going, and the sites are not on the National Priorities List (NPL).

ADEQ staff will continue to monitor water quality and flow over the next several years during varied flow stages. The Hassayampa River is scheduled for more intensive ambient monitoring as a part of the Fixed Station Network (FSN) rotating watershed approach in WY 2002 and 2007. This approach targets two watersheds each year over a five year period. The FSN Program will collect water quality samples and flow measurements of the Hassayampa River quarterly at the MGHSR104.90 and MGHSR089.37 sites. For WY 2002, two of the sampling events have already been performed; two more are scheduled. The watershed will be sampled again by the FSN Program in WY 2007.

The ADEQ TMDL Program will continue to collect samples and flow measurements the Hassayampa River (HUC#15070103-007A) at the sites below Wetlands; above, below and at the Maple Gulch drainage; above and below Senator Mine, and from the adit discharge. The sampling will concentrate on rainfall/runoff events to better characterize the loading from the tailings piles and to better characterize in stream attenuation of dissolved metals. In anticipation of Maple Gulch being added to the 303(d) List, the sampling will attempt to identify discrete sources in the Maple Gulch drainage. Other objectives of the continuing sampling efforts will be to confirm that the smaller tailings piles and shafts are not causing or contributing to a local exceedance of surface water quality standards, and to develop a discharge rating curve at selected sites so that the appropriateness of the selected critical conditions can be confirmed. The data collected by these programs will be used to develop the implementation plan in the second phase of the TMDL.

Removing and/or capping the Wetland, McClell, and Senator Mine tailings piles, remediating the Senator Mine adit drainage and/or closing the Senator Mine adit should

reduce dissolved cadmium, copper, and zinc loads to within standards. These suggested strategies are general and not to be construed as requirements; site specific studies must be undertaken before selection, design and implementation can be accomplished.

The Arizona Revised Statutes (2000) do not contain specific language that allows enforceable actions to be taken against non point sources of pollution. Implementation plans for non point source TMDLs depend solely upon the volunteer approach of land managers (A.R.S. §49-234). Cooperation of state and federal agencies and private landowners will be paramount in the implementation of these TMDLs.

Watershed projects will be started incrementally as they are funded. ADEQ and other agencies have grant funding available to assist in implementing watershed restoration plans. After the TMDL implementation plan has been adopted, ADEQ will review the status of the waterbody at least once every five years to determine if compliance with applicable surface water quality standards has been achieved. If compliance with applicable surface water quality standards has not been achieved, ADEQ will evaluate whether modification of the TMDL implementation plan is required (A.R.S. § 49-234).

Table 7. Monitoring and Implementation Actions

Actions:	WY 2002	WY 2003	WY 2004	WY 2005	WY 2006	WY 2007
Ambient monitoring by FSN	X					X
Targeted sampling	X	X	X	X	X	X
Reevaluate progress			X			X
Review status/ modify implementation						X

6.0 PUBLIC PARTICIPATION

Public participation was encouraged and received throughout the development of this TMDL investigation. USFS personnel from Prescott National Forest, Bradshaw Ranger District accompanied ADEQ on three sampling trips, and the US EPA accompanied ADEQ personnel on one sampling trip. The draft TMDLs were made available for a public comment period lasting 30 days starting April 29, 2002. Public notice of the availability of the draft document was posted in a newspaper of general circulation, the *Prescott Daily Courier*; by email notifications; phone calls; and the ADEQ website (<http://www.adeq.state.az.us>). The draft TMDLs were available for review at the ADEQ library and the Prescott Public Library. Additionally, ADEQ mailed copies of the draft TMDLs to staff at the USFS, US EPA, Arizona Department of Game and Fish, Yavapai County, and other interested parties. A public meeting was held on May 15, 2002 at the

Prescott Public Library. ADEQ received no comments pursuant to the 30 day public notice. The draft TMDLs were then published for 45 days in the Arizona Administrative Record as required per A.R.S. §49-234.

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Appendix A
(Summary of Listing Data)

Summary of Original Listing Data

STREAM NAME SEGMENT WATERBODY ID DESIGNATED USES	AGENCY PROGRAM SITE DESCRIPTION SITE ID	SAMPLES	PARAMETER UNITS (mg/L)	STANDARD	RANGE OF RESULTS (MEDIAN)	FREQUENCY STANDARD EXCEEDED	USE SUPPORT	COMMENTS
Hassayampa River headwaters-Blind Indian AZ15070103-007 A&Ww, FC, FBC, AgI, AgL	ADEQ Fixed Station Network Near Wagoner, below Milk Creek MGHSR063.02	1991 - 4 water 1992 - 4 water 1993 - 6 water 1995 - 5 water 1996 - 5 water	Dissolved oxygen mg/l	6.0 (90% saturation)	4.65-10.6	3 of 14	Full	Naturally low dissolved oxygen during low flows.
			Mercury (total)	0.6	1.6<detect	1 of 19	Full	
			Turbidity NTU	50	0.21-91	1 of 19	Full	
	ADEQ Biocriteria Program Below Board Creek MGHSR076.00	1992 - 1 water, bugs 1993 - 1 water, bugs 1994 - 1 water, bugs	Ok				Full	
	ADEQ Special Investigation Below Senator Mine MGHSR076.76	1992 - 4 water	Cadmium	varies (7.5-22)	20-56.4	2 of 2	Non A&Ww	
			Cadmium (total)	50	17.5-81.3	3 of 4	Non AgI AgL	
			Cadmium (total)	70	17.5-81.3	2 of 4	Partial FBC	
			Copper	varies (29.5)	12-580	1 of 2	Non A&Ww	
			Copper (total)	500	55-1140	2 of 4	Non AgL	
			Lead (total)	100	>10-110	1 of 4	Partial AgL	
			Turbidity	50	2.0-108	1 of 4	Partial A&Ww	
			Zinc (dissolved)	varies (183-426)	1140-3570	2 of 2	Non A&Ww	
			pH	6.5-9.0	5.28-7.91	1 of 4	Partial A&Ww,	
	ADEQ Special Investigation Above Senator Mine MGHSR076.88	1992 - 4 water	Cadmium	varies (6-25)	15-65	2 of 2	Non A&Ww	
			Cadmium (total)	50	4.5-70	1 of 4	Partial AgL/AgI	
			Copper	varies (24-83)	14-280	1 of 2	Non A&Ww	
			Zinc (dissolved)	varies (150-	830-3900	2 of 2	Non A&Ww	
	USFS Cooperative Monitoring Below Senator Mine MGHSR077.20	1991 - 3 water 1993 - 2 water	Ok				Full	
	USFS Cooperative Monitoring At 79B MGHSR077.89	1991 - 1 water	Ok				Full	

Source: ADEQ. 2000. The Status of Water Quality in Arizona. Clean Water Act Section 305(b) Report 2000.

Appendix B
(Hassayampa River TMDL Project Plan)




TMDL PROJECT PLAN FOR:
HASSAYAMPA RIVER
HUC# 15070103-007

October 18, 2000

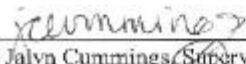
TOTAL MAXIMUM DAILY LOAD (TMDL) PROJECT PLAN

HASSAYAMPA RIVER
HUC# 15070103-007

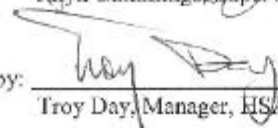
APPROVALS

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I. BACKGROUND INFORMATION

This project will develop a TMDL analysis of cadmium, copper and zinc for the Hassayampa River (HUC# 15070103-007) near Prescott, Arizona. ADEQ expects to submit a TMDL Draft Report to the US EPA by June 30, 2001.

TABLE 1: SITE DESCRIPTION

Waterbody Name	Hassayampa River - headwaters to Blind Indian Creek
Waterbody HUC ID	15070103-007
Reach Length	approx. 31 mi
Listed Reach	<u>Designated Uses:</u> Aquatic and Wildlife warmwater*, Fish Consumption, Full Body Contact, Agricultural Irrigation, and Agricultural Livestock Watering. Non-support of A&W
Parameters Listed	dissolved cadmium, dissolved copper, dissolved zinc
Land Uses	recreation, timber harvesting, grazing, mining, wildlife (Prescott National Forest); ranching
Potential Sources	abandoned mining operations, naturally mineralized soils

- * The reach's designated use of A&Ww may be changed to A&Wc for elevations above 5000 ft. upon approval of the Water Quality Standards draft.

II. SAMPLING SCHEDULE

TABLE 2: SAMPLING SCHEDULE

WATER YEAR	SAMPLING DATES	COMMENTS
Jan - Mar 2000	Feb 9-11, 2000	12 water quality samples
Apr - Jun 2000		not sampled
Jul - Sep 2000	Sep 25-27, 2000	3 water quality samples, very low flow
Oct - Dec 2000	Nov, 2000	11 water quality samples, 2 duplicates
Jan - Mar 2001	Feb, 2001	15 water quality samples, 2 split samples, 2 filter blanks
Apr - Jun 2001	Apr, 2001	15 water quality samples, 2 split samples, 2 filter blanks

III. LOCATION OF SAMPLE SITES

A map of the listed reach and sample site locations is attached.

TABLE 3: SITE ID AND DESCRIPTION

SITE ID	SITE DESCRIPTION
MGHSR081.07	at confluence with Blind Indian Creek
MGHSR086.72	on tributary behind Walnut Grove school
MGHSR089.37	at USGS gaging station #9515000 (no data since 1983)
MGHSR099.44	at river on USFS road 710 (near Climax Mine)
MGHSR102.30	between MGHSR099.44 and MGHSR108.17
MGHSR108.17	at river on USFS road 79 past Whispering Pines Campsite
MGHSR109.45	downstream of Senator Mine
MGHSR109.55	at Senator Mine
MGHSR109.65	upstream of Senator Mine (FSN site HR-5)
MGHSR109.85	downstream of McCleur tributary confluence
MGHSR109.95	at confluence with McCleur tributary
MGHSR110.05	upstream of McCleur tributary confluence
MGHSR110.65	upstream of lake 200 ft downstream of tailing pile
MGHSR111.45	downstream of headwaters where stream crosses trail
MGHSR112.14	headwaters

IV. TARGET ANALYTES

TABLE 4: TARGET ANALYTES AND STANDARDS

STANDARDS	A&Ww* ACUTE3 (µg/L)	A&Wc* ACUTE3 (µg/L)	A&Ww OR C* CHRONIC4 (µg/L)
Cadmium, dissolved	$e^{(1.128[\ln(\text{Hardness}^{**})]-2.0149)}$	$e^{(1.128[\ln(\text{Hardness}^{**})]-3.828)}$	$e^{(0.7852[\ln(\text{Hardness}^{**})]-3.490)}$
Copper, dissolved	$e^{(0.9422[\ln(\text{Hardness}^{**})]-1.464)}$	$e^{(0.9422[\ln(\text{Hardness}^{**})]-1.464)}$	$e^{(0.8545[\ln(\text{Hardness}^{**})]-1.465)}$
Zinc, dissolved	$e^{(0.8473[\ln(\text{Hardness}^{**})]+0.860]}$	$e^{(0.8473[\ln(\text{Hardness}^{**})]+0.860]}$	$e^{(0.8473[\ln(\text{Hardness}^{**})]+0.761]}$

* The standards for cadmium (A&Ww) and zinc (A&Ww and A&Wc) may change upon approval of the Water Quality Standards draft.

** Hardness is expressed as mg/L CaCO₃ and is calculated by the laboratory.

V. SAMPLE COLLECTION PROCEDURES

Samples are collected using ADEQ collection techniques (detailed in the Fixed Station Network Procedures Manual). Any deviations are noted.

Grab samples to be analyzed for dissolved metals are collected in 500mL plastic containers and are field filtered immediately using the GeoPump. (If time and equipment constraints do not allow for field filtration, lab filtration is acceptable). After filtration, HNO₃ is added to minimize precipitation and adsorption on container walls. Hardness data are also obtained from these preserved samples.

Chain-of-custody procedure is followed to ensure sample integrity and control from the time of collection until data reporting. The process includes sample labels, sample seals, the field log book, chain of custody record, and receipt of sample by laboratory.

VI. FIELD MEASUREMENTS AND EQUIPMENT

Field data are collected using ADEQ collection techniques (detailed in the Fixed Station Network Procedures Manual). Any deviations are noted. General field measurements of water quality data are obtained with a Hydrolab Surveyor. These measurements include:

- water temperature (EC)
- dissolved oxygen (mg/l & % saturation)
- specific conductance (µS)
- pH

Other measurements/equipment include:

- air temperature (EC)
- discharge (cfs) with Marsh-McBirney current velocity meter and wading rod or, in cases of very low flow, without the wading rod (gross flow estimate). If flow is extremely low, a flow measurement may not be possible.
- handheld GPS receiver to locate sample sites

All field measurements and observations are recorded on field sheets (a sample field sheet is attached). All sites are photographed during each visit. Field equipment is maintained and calibrated in accordance with manufacturer's instructions, the FSN Procedures Manual for Surface Water Quality Monitoring, and the TMDL Unit Standard Operating Procedures Manual.

VII. ANALYTICAL METHODS

The laboratory selected for this project is:

Bolin Laboratories, Inc.
17631 North 25th Avenue
Phoenix, AZ 85023
602-942-8220

PO# EW673760

TABLE 5: TARGET ANALYTES AND METHODS

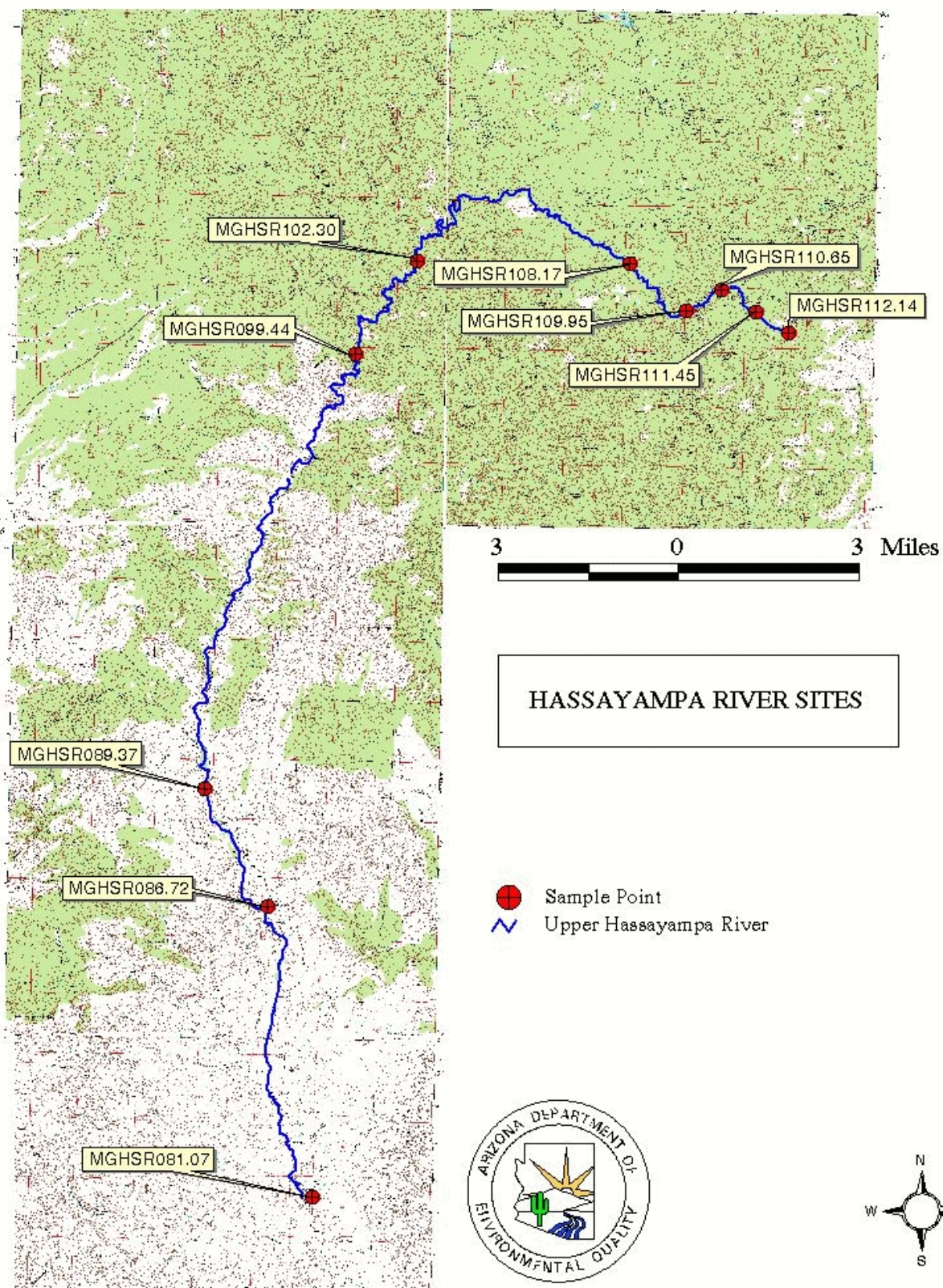
TARGET ANALYTE	UNITS	METHOD
Hardness (CaCO ₃)	mg/L as CaCO ₃	EPA 130.2
Cadmium, dissolved	µg/L	EPA 200.7
Copper, dissolved	µg/L	EPA 200.7
Zinc, dissolved	µg/L	EPA 200.7

TABLE 6: ESTIMATED LABORATORY COSTS

ANALYSIS	UNIT COST	NUMBER OF SAMPLES	NUMBER OF EVENTS	TOTAL COSTS
Calcium	\$9.60	19	3	\$547.20
Magnesium	\$9.60	19	3	\$547.20
Filtration for dissolved metals	\$10.00	19	3	\$570.00
Metals digestion for ICP	\$16.00	19	3	\$912.00
Hardness (CaCO ₃)	\$0.00	19	3	\$0.00
Cadmium, dissolved	\$9.60	19	3	\$547.20
Copper, dissolved	\$9.60	19	3	\$547.20
Zinc, dissolved	\$9.60	19	3	\$547.20
TOTAL ESTIMATED LABORATORY COSTS				\$4218.00

VIII. QUALITY ASSURANCE AND QUALITY CONTROL

QC samples are collected at a rate of at least 10% of total regular samples. When the proposed 19 samples are collected, then two filter blank samples and two split samples are collected. When there are less than ten samples, one filter blank sample and one split sample are collected.



Appendix C
(TMDL Program Sampling Data)

Site Name	Site ID (time)	Date	Air Temp (° F)	Water Temp (° C)	pH (SU)	Flow (cfs)	Hardness (mg/L)	Cadmium, dissolved (µg/L)	Cadmium, total (µg/L)	Copper, dissolved (µg/L)	Copper, total (µg/L)	Zinc, dissolved (µg/L)	Zinc, total (µg/L)
SPRING	MGHSR112.14	3/23/01	N/A	4.45	5.53	0.091	16	<5	<5	<15	<15	<20	20
ASPEN	MGHSR111.45	11/7/00	-0.4	7.19	5.35	NM	47	<5	N/A	<15	N/A	30	N/A
		1/10/01	N/A	N/A	N/A	no flow	N/A	N/A	N/A	N/A	N/A	N/A	N/A
		2/13/01	32.7	2.97	5.95	0.067	35	<5	<5	<15	19	30	<20
		3/23/01	N/A	4.51	6.28	1.198	16	<5	<5	<15	21	<20	30
		4/10/01	N/A	4.39	6.16	0.046	23	<5	<5	<15	16	<20	20
WETLANDS	MGHSR110.65	9/27/00	64.8	13.15	6.86	NM	220	4	4	43	110	380	410
		11/7/00	-3.5	2.3	5.79	NM	77	<5	N/A	90	N/A	200	N/A
		1/10/01	23.70	0.63	6.33	0.070	113	<5	<5	59	111	370	370
		2/13/01	34.5	0.65	6.47	0.350	65	<5	<5	25	36	100	110
		3/23/01	N/A	7.3	6.69	3.973	28	<5	<5	38	57	40	50
		4/10/01	N/A	2.19	6.81	0.424	55	<5	<5	39	84	100	150
		6/7/01	N/A	20.1	7.05	0.019	123	<5	<5	65	108	340	370
	11:35	8/7/01	N/A	15.78	7.07	0.003	155	5	5	29	80	560	640
	13:25	8/7/01	N/A	15.76	6.50	0.003	148	<4	6	20	240	390	710
ABV MCCLEUR	MGHSR109.98	11/7/00	-1.4	3.82	6.48	NM	90	<5	N/A	17	N/A	50	N/A
		1/10/01	N/A	1.39	6.95	0.155	87	<5	<5	<15	<15	30	40
		2/13/01	32.2	1.48	6.93	0.397	72	<5	<5	<15	18	60	50
		3/23/01	N/A	6.16	8.16	4.367	35	<5	<5	27	42	40	50
		4/10/01	N/A	5.16	7.23	0.455	57	<5	<5	20	36	60	60
		6/7/01	N/A	13.2	6.74	NM	87	<5	<5	<15	<15	40	160
	11:09	8/7/01	N/A	N/A	N/A	0.053	97	<4	<4	<10	130	<20	300
	11:39	8/7/01	N/A	N/A	N/A	N/A	398	<4	7	<10	700	<20	840
	12:09	8/7/01	N/A	N/A	N/A	N/A	119	<4	<4	<10	320	<20	400
	12:39	8/7/01	N/A	N/A	N/A	N/A	188	<4	<4	<10	250	<20	350

	13:09	8/7/01	N/A	15.7	6.88	0.053	149	<4	<4	<10	180	<20	260
	13:39	8/7/01	N/A	N/A	N/A	N/A	114	<4	<4	<10	100	20	170
	14:09	8/7/01	N/A	N/A	N/A	N/A	106	<4	<4	<10	70	<20	200

Site Name	Site ID	Date	Air Temp (° F)	Water Temp (° C)	pH (SU)	Flow (cfs)	Hardness (mg/L)	Cadmium, dissolved (µg/L)	Cadmium, total (µg/L)	Copper, dissolved (µg/L)	Copper, total (µg/L)	Zinc, dissolved (µg/L)	Zinc, total (µg/L)
ABV MCCLEUR	14:39	8/7/01	N/A	N/A	N/A	N/A	100	<4	<4	<10	60	<20	100
	15:09	8/7/01	N/A	N/A	N/A	N/A	95	<4	<4	<10	40	<20	80
	15:39	8/7/01	N/A	15.19	7.14	N/A	95	<4	<4	<10	40	<20	80
	16:09	8/7/01	N/A	15.18	7.36	N/A	89	<4	<4	<10	20	<20	60
	16:39	8/7/01	N/A	15.06	7.33	N/A	85	<4	<4	<10	10	20	40
MCCLEUR	MGMPG000.01	11/7/00	-1.4	1.47	3.41	NM	322	28	N/A	4077	N/A	2280	N/A
		1/10/01	N/A	1.16	3.55	0.005	284	35	34	2504	2455	2970	2800
		2/13/01	34.9	0.82	3.98	0.031	294	37	37	2830	2832	3070	3030
		3/23/01	N/A	7.27	4.05	1.189	90	21	19	1520	1670	1820	1690
		4/10/01	N/A	1.91	3.83	0.080	161	23	23	2174	2147	2080	2000
		6/7/01	N/A	13	3.38	0.005	177	24	41	1994	2062	1970	2010
	13:00	8/7/01	N/A	15.82	3.6	0.111	291	20	22	1730	2130	1020	1320
	14:15	8/7/01	N/A	15.36	3.84	N/A	196	20	20	1400	1530	1300	1360
	15:30	8/7/01	N/A	15.24	3.87	N/A	187	21	21	1440	1570	1450	1460
	16:30	8/7/01	21	14.97	3.88	N/A	192	23	23	1560	1760	1660	1680
BLW MCCLEUR	MGHSR109.95	11/7/00	-1.4	3.44	5.53	NM	117	<5	N/A	509	N/A	400	N/A
		1/10/01	N/A	1.36	5.38	0.079	113	<5	<5	146	334	390	410
		2/13/01	32.9	1.14	6.29	0.422	105	6	6	345	438	510	500
		3/23/01	N/A	6.37	6.81	4.680	55	<5	5	285	452	460	460
		4/10/01	N/A	4.5	6.45	0.795	70	<5	<5	241	407	380	400
		6/7/01	N/A	16.2	6.00	0.028	131	11	13	575	976	870	940
ABV SENATOR	MGHSR109.78	11/7/00	-2	2.86	6.22	NM	120	<5	N/A	437	N/A	380	N/A
		1/10/01	N/A	1.08	6.38	0.220	113	<5	<5	103	171	280	300
		2/13/01	N/A	0.83	6.88	0.370	110	5	6	328	886	480	590

		3/23/01	N/A	7.12	6.86	4.700	55	<5	5	296	443	450	460
		4/16/01	N/A	14.39	8.42	0.370	77	<5	5	110	486	384	450
		6/7/01	N/A	12.9	6.00	0.034	134	<5	<5	115	116	340	350
	11:45	8/7/01	N/A	15.73	7.18	1.660	143	<4	5	30	680	70	510
Site Name	Site ID (time)	Date	Air Temp (° F)	Water Temp (° C)	pH (SU)	Flow (cfs)	Hardness (mg/L)	Cadmium, dissolved (µg/L)	Cadmium, total (µg/L)	Copper, dissolved (µg/L)	Copper, total (µg/L)	Zinc, dissolved (µg/L)	Zinc, total (µg/L)
ABV SENATOR	12:52	8/7/01	N/A	15.83	5.09	0.132	202	13	16	510	860	730	940
	13:18	8/7/01	N/A	15.83	4.98	0.132	197	19	19	1240	1440	1030	1050
	13:41	8/7/01	N/A	15.8	5.2	0.083	204	18	19	1300	1620	1020	1110
	15:08	8/7/01	N/A	15.78	5.98	0.321	167	12	13	540	750	750	780
	16:00	8/7/01	N/A	15.73	6.96	0.092	155	10	11	280	450	630	680
SENATOR ADIT	MGHSR109.75	1/10/01	N/A	9.02	7.66	0.042	466	31	33	<15	22	3160	3350
		2/13/01	N/A	2.84	8.08	0.074	450	34	39	<15	34	3500	4450
		3/23/01	N/A	18.68	7.37	0.074	415	161	157	41	248	13000	15300
		4/16/01	N/A	19.12	7.34	0.123	475	52	56	17	115	5040	5700
SENATOR ADIT	MGHSR109.75	6/7/01	N/A	13.28	6.86	0.072	457	45	47	20	104	5120	5220
	11:45	8/7/01	N/A	13.17	7.35	0.066	388	29	56	10	600	3040	6410
	13:02	8/7/01	N/A	12.75	7.00	0.057	460	38	40	<10	60	4400	4620
	13:24	8/7/01	N/A	12.62	7.00	0.058	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	13:58	8/7/01	N/A	N/A	N/A	0.040	468	38	41	<10	60	4370	4790
	16:00	8/7/01	N/A	12.6	7.65	0.036	454	37	40	<10	50	4240	4700
		1/28/02	N/A	7.96	8.25	NM	458	28	37	<10	<10	2680	2900
BLW SENATOR	MGHSR109.68	11/7/00	-2.1	2.49	6.31	NM	148	8	N/A	348	N/A	720	N/A
		1/10/01	50.40	3.02	7.21	0.146	178	11	11	65	98	1060	1080
		3/23/01	N/A	7.97	7.00	5.403	60	8	8	315	449	720	770
		6/7/01	N/A	14.75	7.53	0.078	387	34	36	29	58	3450	3630
WHISPER	MGHSR108.17	9/27/00	74.7	16.35	6.75	NM	300	5	5	<10	13	510	520
		11/7/00	3.3	3.62	6.48	NM	171	7	N/A	190	N/A	680	N/A
		1/10/01	51.80	3.35	7.11	0.303	177	5	5	16	29	500	520

		3/23/01	N/A	9.82	8.36	6.762	67	6	6	207	296	510	550
		4/10/01	N/A	2.55	7.54	1.337	122	6	7	68	150	480	620
		6/6/01	N/A	21.07	6.55	0.024	263	<5	5	<15	26	330	370
	12:20	8/7/01	N/A	17.42	7.18	0.133	321	7	7	10	20	370	400
Site Name	Site ID (time)	Date	Air Temp (° F)	Water Temp (° C)	pH (SU)	Flow (cfs)	Hardness (mg/L)	Cadmium, dissolved (µg/L)	Cadmium, total (µg/L)	Copper, dissolved (µg/L)	Copper, total (µg/L)	Zinc, dissolved (µg/L)	Zinc, total (µg/L)
WHISPER	16:30	8/7/01	N/A	17.54	7.19	0.242	342	7	8	10	20	400	430
JERSEY	MGHSR104.90	4/16/01	N/A	14.16	8.17	1.206	131	<5	<5	<15	18	70	90
		6/6/01	N/A	18.65	6.66	0.074	207	<5	<5	<15	<15	80	100
		8/7/01	N/A	N/A	N/A	no flow	N/A	N/A	N/A	N/A	N/A	N/A	N/A
		1/28/02	N/A	2.6	6.54	0.043	293	<4	<4	<10	<10	120	140
CLIMAX	MGHSR099.44	4/16/01	N/A	11.5	6.51	1.882	201	<5	<5	<15	22	20	30
CLIMAX ADIT		7/27/01	N/A	N/A	N/A	N/A	115	<4	<4	<10	<10	<20	20
GAGE	MGHSR089.37	9/26/00	89.2	21.9	7.31	NM	260	<1.0	<1.0	<10	<10	<50	<50
		11/6/00	8.3	14.7	7.37	NM	278	<5	N/A	<15	N/A	<20	N/A
		1/29/01	33.60	11.09	7.74	1.289	245	<5	<5	<15	<15	<20	<20
		2/23/01	N/A	17.02	8.37	1.216	254	<5	<5	<15	<15	30	<20
		3/29/01	N/A	15.09	8.01	1.098	185	<5	<5	<15	<15	<20	<20
		4/17/01	N/A	21.53	7.74	1.365	259	<5	<5	<15	<15	<20	<20
GAGE	MGHSR089.37	6/6/01	N/A	18.8	7.40	0.665	222	<5	<5	<15	<15	<20	<20
WALNUT	MGHSR086.72	11/6/00	5.9	12.24	7.84	NM	287	<5	N/A	<15	N/A	<20	N/A
MILK CREEK	MGHSR083.47	1/29/01	N/A	N/A	N/A	N/A	239	<5	<5	<15	<15	<20	<20
		2/23/01	N/A	12.46	7.98	2.269	211	<5	<5	<15	<15	40	<20
		3/29/01	N/A	17.06	7.41	1.498	185	<5	<5	<15	<15	<20	30
		4/17/01	N/A	N/A	N/A	1.384	258	<5	<5	<15	<15	<20	40
		6/6/01	N/A	18.96	6.77	1.012	240	<5	31	<15	82	<20	90
BLIND INDIAN	MGHSR081.07	11/6/00	9.4	13.96	7.40	NM	288	<5	N/A	<15	N/A	<20	N/A
		2/23/01	N/A	9.85	8.18	3.914	249	<5	<5	<15	<15	<20	<20

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		3/29/01	N/A	16.15	8.21	0.977	175	<5	<5	<15	<15	<20	<20
		4/17/01	N/A	21.14	8.04	0.643	266	7	<5	<15	<15	<20	<20
		6/6/01	N/A	23.58	7.40	1.193	287	<5	<5	<15	<15	<20	20